



**BOSC**

BOARD OF SCIENTIFIC COUNSELORS

# REPORT OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY BOARD OF SCIENTIFIC COUNSELORS AIR, CLIMATE, AND ENERGY (ACE) SUBCOMMITTEE

## RESPONSES TO CHARGE QUESTIONS

### BOSC Air, Climate, and Energy Subcommittee

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## LIST OF ACRONYMS

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ACE	Air, Climate, and Energy	HFCs	Hydrofluorocarbons
ARS	Agricultural Research Service	HS	Homeland Security
BOSC	Board of Scientific Counselors	IAS	Interagency agreements
CH <sub>4</sub>	Methane	ICLUS	U.S. EPA Integrated Climate and Land-Use Scenarios project
CO	Carbon monoxide	IDF	Intensity, duration, and frequency
CO <sub>2</sub>	Carbon dioxide	IPCC	Intergovernmental Panel on Climate Change
CMAQ	Community Multiscale Air Quality Modeling System	LASSO	U.S. EPA Locating and Selecting Scenarios Online tool
COMET	City-based Optimization Model for Energy Technologies	NAAQS	National Ambient Air Quality Standards
COVID-19	Coronavirus Disease 2019	NADP	National Atmospheric Deposition Program
CPHEA	U.S. EPA Center for Public Health and Environmental Assessment	NGEM	Next Generation Emission Monitoring
CSS	Chemical Safety for Sustainability	NOAA	National Oceanic and Atmospheric Administration
DOE	U.S. Department of Energy	NREL	National Renewable Energy Laboratory
EPA	U.S. Environmental Protection Agency	ORD	U.S. EPA Office of Research and Development
EPIC	Environmental Policy Integrated Climate	OTAQ	U.S. EPA Office of Transportation and Air Quality
EtO	Ethylene oxide	PFAS	Per- and Polyfluoroalkyl substances
EV	Electric vehicle	PM <sub>2.5</sub>	Particulate matter less than 2.5 microns in diameter
FEM	Federal Equivalent Model	PNNL	Pacific Northwest National Laboratory
FRM	Federal Reference Model	RFS	Renewable Fuel Standard
GCAM-USA	Global Change Analysis Model	SOAs	Secondary organic aerosols
GHG	Greenhouse gas		
GLIMPSE	GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator		
GWP	Global warming potential		
HERA	Health and Environmental Risk Assessment		

SHC	Sustainable and Healthy Communities	TOF	Total organic fluoride
		USDA	U.S. Department of Agriculture
SSWR	Safe and Sustainable Water Resources	VCPs	Volatile chemical products
StRAP	Strategic Research Action Plan	VOCs	Volatile organic compounds

## INTRODUCTION

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The mission of the U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD) is to provide the best available science and technology to inform and support public health and environmental decision-making at the federal, state, tribal, and local levels, addressing critical environmental challenges and anticipating future needs through leading-edge research. The ORD's Air, Climate, and Energy (ACE) research program focuses on the science and engineering needed to improve air quality, reduce the number of nonattainment areas in the United States, and protect public health and the environment, including an emphasis on addressing the Administration priorities of addressing the climate crisis and environmental justice issues. The ACE program is one of the Agency's six highly integrated national research programs. The other five are Chemical Safety for Sustainability (CSS), Homeland Security (HS), Health and Environmental Risk Assessment (HERA), Safe and Sustainable Water Resources (SSWR), and Sustainable and Healthy Communities (SHC).

ORD developed Strategic Research Action Plans (StRAPs) to guide each research program. The 2019–2022 StRAP<sup>1</sup> for the ACE program articulates the program objectives and a four-year strategy for delivering air, climate, and energy-related research to address EPA's strategic objectives and mandates, as identified in the FY 2018–2022 EPA Strategic Plan (EPA Strategic Plan)<sup>2</sup>. It is the third such strategic planning exercise in this format (previous StRAPs covered 2012–2016 and 2016–2019).

The EPA Board of Scientific Counselors (BOSC) ACE Subcommittee was asked in 2019 to review and comment on the strategic directions and priorities of the program as articulated in the third StRAP. Subsequently, the Subcommittee undertook a review of the program's implementation of the research priorities. This is the second of two reports in 2021 (the first is dated August 2021) that convey the findings of the implementation review. All BOSC reports can be found on the EPA BOSC [website](#).<sup>3</sup>

## BACKGROUND

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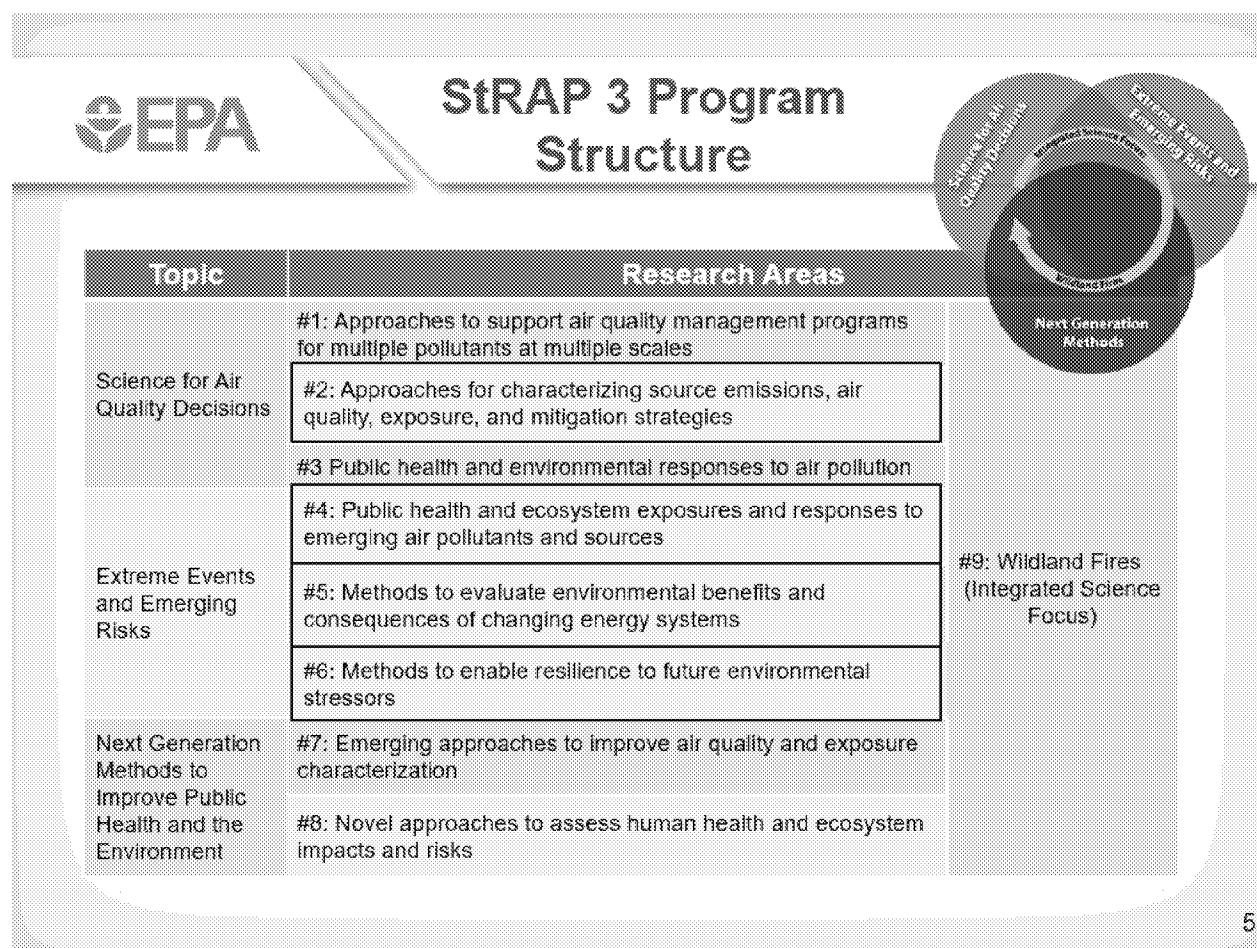
The current ACE research program is organized around three interrelated topics: (1) Science for Air Quality Decisions; (2) Extreme Events and Emerging Risks; and (3) Next Generation Methods to Improve Public Health and the Environment. The ACE StRAP further subdivided each of the three high-level research topics into eight research areas, plus an integrated research area focused on wildland fires. The following figure from a presentation by the program to the BOSC is an overview of the ACE program structure, showing the three research topics and nine research areas.

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<sup>1</sup> Air and Energy National Research Program, *Strategic Research Action Plan, 2019 – 2022*, EPA 601K20003 March 2020, available at [https://www.epa.gov/sites/production/files/2020-10/documents/A-E\\_fy19-22\\_strap\\_final\\_2020.pdf](https://www.epa.gov/sites/production/files/2020-10/documents/A-E_fy19-22_strap_final_2020.pdf)

<sup>2</sup> Working Together, FY 2018-2022 U.S. EPA Strategic Plan, available at <https://www.epa.gov/planandbudget/strategicplan>

<sup>3</sup> <https://www.epa.gov/bosc/air-and-energy-subcommittee>

**Figure 1. Overview of the ACE Research Program Structure**

The August 2021 BOSC ACE report focused on research implementation in six of the nine research areas: 1, 2 (with an emphasis on criteria pollutants), 3, 7, 8, and 9. This report focuses on implementation of research in Research Areas 4, 5, and 6, with an additional review of Research Area 2 emphasizing air toxics and emerging pollutants of concern rather than criteria air pollutants (highlighted in Figure 1 above).

1. Met virtually with the ACE National Program Director and program staff on October 12–14, 2021;
2. Deliberated as a group on the charge questions; and
3. Divided into three charge question teams to draft initial responses to each charge question.

The BOSC ACE Subcommittee meeting agenda (Appendix A) and briefing materials (listed in Appendix B) are available on EPA's [website](https://www.epa.gov/bosc).<sup>4</sup>

The three Subcommittee charge question teams drafted specific responses to each charge question after the October 2021 meeting and the Subcommittee met again on October 27, 2021 to discuss and review

<sup>4</sup> <https://www.epa.gov/bosc>

progress and key themes for charge question responses as an entire Subcommittee. A more complete draft report, including overview and summary materials prepared by the Chair and Vice Chair of the Subcommittee, was discussed by the Subcommittee in a meeting of the entire Subcommittee on November 12, 2021.

The report was then further revised based on Subcommittee member comments and discussions during that meeting and finalized in the BOSC Executive Committee meeting on February 3-4, 2022. The recommendations of the ACE Subcommittee in the report are based on material provided to us prior to and after the October 2021 meeting, presentations made during the three-day meeting, and deliberations both during and after the meeting.

## CHARGE QUESTIONS AND CONTEXT

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The ACE Subcommittee was charged with three questions as follows:

Q.1: The ACE research program is implementing research to develop new methods to quantify source and near-source emissions, as well as ambient levels, of toxic air pollutants and contaminants of emerging concern. These methods are needed to identify pollutant sources and levels of exposure for communities and individuals.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD's implementation of its air toxics and contaminants of emerging concern measurements methods research, and how this research will improve our understanding of these pollution sources and exposures, particularly for disproportionately impacted communities? [RA1, RA2, RA4]*

Q.2: Climate change is expected to continue to increase the negative environmental and human health impacts of wildfires, flooding, drought, and other extreme events. Developing the knowledge and approaches to build resilience and adapt to these events is critical to preparing communities and protecting vulnerable populations and ecosystems.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD's implementation of research to understand effects of climate-driven changes on natural and human systems, adverse impacts on human health and the environment from climate stressors, and approaches to prevent or reduce these impacts? [RA6]*

Q.3: The Nation's energy and transportation systems are experiencing major transformations in response to economic drivers and to meet the Biden Administration's goal of net-zero carbon emissions by 2050. Understanding the dynamic changes in these complex, interconnected systems is important for understanding impacts of policies and technology changes on emissions of greenhouse gases, air pollutants, and other health and environmental impacts.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD's implementation of its research portfolio to gain a better understanding of how energy and transportation systems may evolve and the consequences for emissions and other impacts. [RA5]*

Overall, the Subcommittee found that the ACE program has made significant progress in support of their strategic priorities, with important and impactful products and outcomes. The quality and impact of the science done in the program is excellent. Details are provided in the specific responses to the charge questions, below. This review also provided an opportunity to revisit topics brought up in earlier meetings



by the Subcommittee, including climate change, environmental justice, partner engagement, and a clearer integration of energy within the research portfolio. The scientific community increasingly recognizes the importance and urgency of addressing climate change. While rewarding to see the “C” (Climate) in ACE reinstated, the Subcommittee acknowledges that the program has continued to work on this important issue, integrating it into their strategic priorities and plans. The ACE program has successfully designed and executed research projects that address key science questions in a way that is relevant to partners and decision-makers. This proactive approach will also be required to address Administration priorities on environmental justice. While EPA has done impactful research on environmental justice issues in the past four years (the cycle of this StRAP), a continued focus on prioritizing this area of research is important to ensure that the health of disproportionately impacted communities is understood and protected. The foundational research conducted over the years by the ACE program has positioned the team well for today’s scientific challenges and poses new opportunities for EPA to take a leadership role in addressing our most pressing environmental problems.

The Subcommittee was also impressed with the breadth and depth of the research staff. Researchers having a diversity of backgrounds, training, and expertise are clearly engaged across the program, bringing new ideas and talents to ACE research at ORD. The Subcommittee encourages the program to continue to work to balance the immediate and shorter-term interests of partners and stakeholders with the longer-term requirements for EPA researchers and their science communities to ensure that the ACE program and ORD have a place for exploratory research on relevant topics. This will help the program continue to lead advancements in environmental science and provide the basis for addressing problems that are not yet evident or well understood. Overall, the Subcommittee believes the ACE program is well positioned for success, now and in the next strategic planning cycle.

## SUBCOMMITTEE RESPONSES TO CHARGE QUESTIONS

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The Subcommittee appreciates the efforts of the ACE program leadership and staff in providing well-organized background materials, clear presentations, and an opportunity to discuss ongoing research projects with program leadership as well as the scientists. The opportunity to hear from and engage with scientists from other geographic locations was particularly appreciated, highlighting the breadth of expertise across the program and the strong connection with regional offices and their specific needs and issues.

The ACE program has continued to make advances in stakeholder and community engagement and outreach. The Subcommittee noted that user needs and perspectives are an important part of the research project design. Increasingly, the team is integrating multiple science disciplines and perspectives to create a more holistic product. The Rubbertown Next Generation Emissions Measurement Project is just one example of successful community outreach and response (CQ1). Other examples include climate relevant information and tools provided to decision-makers (CQ2). The program has developed and is implementing a more formalized structure for partner engagement, including feedback loops, which is clearly benefiting their accomplishments. The Subcommittee encourages continued collaboration with state agencies and other research entities in both its measurement and modeling programs. The program can also benefit from further collaboration with the Center for Public Health and Environmental Assessment (CPHEA) to develop guidance on potential impacts. The CPHEA center’s ethylene oxide (EtO) research, as well as the cross-cutting ORD research and planning on per- and polyfluoroalkyl substances (PFAS) and volatile chemical products (VCPs) are specific examples of how this partnership could enable citizens to make informed decisions on potential exposure and risk (CQ1).

The implementation of research in this StRAP demonstrates that the ACE program is truly integrating social sciences and a systems approach into their program. This has been an early goal of the program leaders, and the investments in social science capabilities and perspectives have served the Agency well, enabling the ACE program to readily integrate the priorities of the new Administration in their research portfolio. It was evident in discussions with the scientists and in the review of the products that the ACE program has made a good start on effectively embedding a focus on environmental justice into the planning and implementation of research projects. Specific products such as the Odor Explorer app and other tools in the Air Sensors Toolbox are specially designed for use by and to provide value to disproportionately impacted communities. These successes demonstrate how the research conducted by ACE can help make substantial progress in protecting the health of these communities. The Subcommittee encourages the ACE program to continue to prioritize the focus on environmental justice as it works to develop and implement its next StRAP.

The Subcommittee was pleased to see the “E” (Energy) in ACE given significant focus at this review. The research and the key products presented by the team reflected an appropriate and timely integration of energy production and its impacts across the research portfolio. That strong linkage was seen both in considering new measurements (brake and tire wear, CQ1) and in the modeling activities (CQ3). Increasing the regional specificity of the models is critical for use by decision-makers and communities. The City-based Optimization Model for Energy Technologies (COMET; CQ3) is an excellent example of a tool that cities and states can use to support long-term energy sector planning. It was clear from the review that the modeling tools and databases developed by the ACE program are increasingly valued and used by both researchers and policymakers outside of EPA. The “science to solutions” perspectives employed by the program are applauded. Additional resources might be required to support the scientists in accomplishing the effective dissemination of results and tools to a broad set of stakeholders.

Specific responses to each of the three charge questions follow below. The responses highlight strengths of the ACE program research areas and provide suggestions on progress to date and potential enhancements to the research program. The responses also include one or more specific recommendations for action by the ACE program leadership and staff for each charge question.

## Charge Question 1

Q.1. The ACE research program is implementing research to develop new methods to quantify source and near-source emissions, as well as ambient levels, of toxic air pollutants and contaminants of emerging concern. These methods are needed to identify pollutant sources and levels of exposure for communities and individuals.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD’s implementation of its air toxics and contaminants of emerging concern measurements methods research, and how this research will improve our understanding of these pollution sources and exposures, particularly for disproportionately impacted communities? [RA1, RA2, RA4]*

### Narrative

The ACE program continues to make good progress on the science behind the measurement methods and on the supporting programs for air toxics and emerging pollutants of concern. The technical work the ACE program has undertaken in Research Areas 2 and 4 is excellent. The treatment of specific toxics and emerging pollutants using a systems or life-cycle approach is evidenced in the advances made to understand PFAS measurement and fate and transport by: (1) development of a method to measure

source emissions, (2) ambient measurement approaches, (3) deposition measurement approaches, and (4) research into mitigation and destruction. ACE program scientists continue to be leaders in developing and testing measurement methods for source characterization, ambient concentrations, and community exposure. These actions dovetail with the larger effort across EPA programs to understand and mitigate PFAS.

To continue its record of success, the ACE program work must balance the interests of EPA partners and stakeholders inside and outside the laboratories with those of the wider ACE research and community partners. Striking the proper balance of work for immediate Agency responses and a commitment to longer-term research on topics relevant to ACE missions and goals will help ensure that the ACE program and ORD as a whole can continue leading advancements in environmental science, while providing regional offices, state and local agencies, and tribal communities with critical information needed to solve regulatory challenges of air toxics and emerging pollutants of concern.

The ACE Subcommittee commends EPA and the ACE program on the extensive work done to characterize VCPs, PFAS, EtO, and other pollutants of concern. Additionally, the work to assess community exposure and bring citizen science into the research plan is commendable. Tools such as the Odor Explorer app and projects such as leveraging of the National Atmospheric Deposition Program (NADP) network in Wisconsin in tribal community areas show that the ACE program is committed to understanding issues in communities. As air quality continues to improve and more areas come into compliance with the National Ambient Air Quality Standards (NAAQS), it is important to highlight the impacts that air pollution continues to have on holistic health, especially for disproportionately impacted communities. The air regulatory community continues to need new insights and tools to address emerging and even more complex pollutants. It is reassuring that the ACE program understands this challenge with its focus on the holistic exploration of climate change on air quality, health, ecosystems, and infrastructure.

The Subcommittee urges the ACE program to continue and expand on the use of community tools to address issues particularly in areas with environmental justice issues. We encourage continued work on the Odor Explorer app as well as the EJSCREEN tool, particularly focusing on developing and expanding guidance on how to interpret findings with these tools. It is critical for the community to understand the potential health impacts from exposures and how to use this information to make informed decisions. Communities need guidance on understanding the severity of pollution exposure including knowing which exposures are acceptable, and which should be avoided.

During the meeting, Dr. Alice Gilliland asked the ACE Subcommittee, “What insights can you offer on the paradigm between use of federal reference methods (FRMs)/federal equivalent methods (FEMs) and sensors that we face as ORD supporting our internal regulatory partners?” The Subcommittee encourages the ACE program to explore creative ways to use sensors to identify potential hotspots and high levels of toxic pollutants (or proxies of toxic pollutants). The ACE program is in a good position to then recommend strategies for how state and local agencies and tribal communities might follow up to better understand the severity and potential risks of a specific pollutant and to provide recommendations/strategies to protect public health. For example, the ACE program needs to be able to advise communities on which odors are toxic and which are just nuisance odors.

### **Strengths**

- The research into VCPs, and in particular, the work to characterize VCP emission using the VCPy tool is an important step to understanding the contribution that these products have on secondary organic aerosols and ozone formation. The Subcommittee commends the ACE program for the time-sensitive

work in characterizing VCPs from sanitizing products that have increased in use since the onset of Coronavirus Disease 2019 (COVID-19).

- The Rubbertown Next Generation Emissions Measurement Project is an example of effective community outreach and a strength of the ACE program's ability to characterize source emissions, air quality, and exposure as well as to investigate public health impacts, environmental exposures, and responses to emerging air pollutants of concern. The ACE program has conducted strong outreach with the community to develop and test the Odor Explorer app. This program will have broad impact in how state and local agencies and tribal communities respond to frequent and difficult community concerns around odors and their health impacts.
- The ACE program is doing commendable work by using a holistic health approach to air pollution and associated health effects. This approach has been needed for a long time to more fully understand how communities are impacted by pollution. Community concerns should be prioritized given limited funding and staff capabilities.
- The extensive work into developing methods to characterize stack and fugitive emissions for air toxics from facilities is an important step to understanding the sources and how to control for those pollutants.
- Efforts going into developing new methods for emerging pollutants of concern have been extremely important. This review demonstrated a large portfolio of specific methods in the outputs of the research area. This could serve as a blueprint to apply to other areas.
- Work on fenceline monitoring in combination with drones to achieve curtain monitoring is especially valuable and we encourage the ACE program to expand this work.
- The ACE program is doing excellent work in PFAS/PFOS. This is a great example of a useful framework for attacking complex problems.
- The Subcommittee commends the ACE program on their work on the SPECIATE database and using that information to estimate source emissions and exposures and to develop mitigation strategies.
- We commend the ACE program on the characterization of emissions from light- and heavy-duty vehicles, specifically brake and tire wear emissions. This work will assist the Agency's understanding of vehicle emissions as the fleet moves to more electrified vehicles. We encourage the ACE program to coordinate with the Office of Transportation and Air Quality (OTAQ) on the needed improvements/enhancements to tire and brake wear emission models. We also encourage the program to work with CPHEA to understand how these exposures impact public health, especially in disproportionately impacted communities.

## Suggestions

- We recognize and commend ORD's current focus on expanding the scientific foundation for identifying and quantifying PFAS in the environment through the development of validated analytical methods for specific PFAS and the use of non-targeted analysis methods, including total organic fluoride (TOF). We encourage the ACE program to continue research into measurement of PFAS, both specific compounds and indicator compounds. In conducting this research, it is important to articulate that only certain PFAS target compounds will be measured. The Subcommittee encourages additional research on understanding the role of air transport and deposition, and subsequent multimedia transport leading to human exposure.
- We encourage leveraging existing nation-wide networks such as NADP to eventually achieve greater understanding of transport and fate of PFAS emissions and other pollutants. In many cases the most difficult and expensive part of an ambient and source test program is collecting samples. Piggybacking on NADP sample collection by modifying test devices to collect additional samples could be cost-effective. Analytical techniques might require additional resources. We encourage the ACE program

to continue collaboration with state agencies and other research entities on developing these methods and developing sensors to get meaningful data.

- The Subcommittee commends the ACE program on the development of the Odor Explorer app. We suggest more guidance from the program on how communities can use sensors with the Odor Explorer app to better understand possible pollutants of concern. Additionally, the Subcommittee suggests the program increase coordination with states and local agencies and tribal communities, especially those with odor standards, so they can follow up on odor reports. This app could also help identify new and emerging pollutants of concern and we encourage the ACE program to couple this with onsite monitoring.
- The Subcommittee suggests that the ACE program continue exploration and development of measurement techniques and instrumentation for field deployment to estimate concentrations and spatial coverage of non-NAAQS pollutants of health concern. For example, the program could propose research to identify sensors with high potential for characterizing a larger suite of volatile organic compounds (VOCs), which are important for secondary aerosol formation, ozone formation, and near-source exposures to toxics. All of this possible work would have high applicability for populations in disproportionately impacted communities and ones with special sensitivities.
- Next Generation Emission Monitoring (NGEM) research using mobile monitoring (e.g., cars instrumented with monitoring equipment) is a good way of surveying pollutant distribution by neighborhood. Building mobile sensor packages that could be added to vehicles might also enhance our ability to investigate smoke from wildfires. The ACE program should connect this work with the Air Sensors toolbox to help citizen scientists use these tools and provide guidance on how to understand results from their investigations.
- The Subcommittee suggests that the ACE program provide more information on clearly delineating how to represent VCPs as a subset of total VOCs and put this in perspective with relation to the other sources of VOCs. The Subcommittee encourages the program (in coordination with other ORD research programs) to collaborate with CPHEA to develop guidance on how emerging pollutants of concern impact public health and to provide understanding of the severity of different concentrations so citizens can make informed decisions to avoid exposure.
- The U.S. Department of Agriculture's (USDA's) BioPreferred Program has been encouraging and certifying thousands of chemicals and products manufactured from natural sources to replace fossil-fuel-derived products. Coordination with this program could aid the ACE program in staying ahead of the game.

## Recommendations

The Subcommittee offers the following recommendations:

**Recommendation 1.1:** Coordinate with states to provide recommendations for consistent and standardized procedures to collect and analyze EtO samples. Recommendations are needed in particular to ensure more sensitive methods are applied consistently and can be compared across agencies.

**Recommendation 1.2:** Develop a strategy for toxicity-linked data (health outcomes) as part of the broad research on understanding the impact of VCPs and secondary organic aerosols (SOAs) on health and the environment. This can help illuminate the specific pollutants causing substantial health effects and the chemical and/or physical properties causing the most toxic effects on communities.

**Recommendation 1.3:** Develop materials (documents/tools) to help the public better understand the outcomes and implications of the significant amount of health-effects research ongoing in the ACE program. Prioritization of public messaging will enable citizens to make more informed choices to avoid exposure.

## Charge Question 2

Q.2. Climate change is expected to continue to increase the negative environmental and human health impacts of wildfires, flooding, drought, and other extreme events. Developing the knowledge and approaches to build resilience and adapt to these events is critical to preparing communities and protecting vulnerable populations and ecosystems.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD's implementation of research to understand effects of climate-driven changes on natural and human systems, adverse impacts on human health and the environment from climate stressors, and approaches to prevent or reduce these impacts? [RA6]*

### Narrative

The Subcommittee thanks the ACE program team for the fullness of the information relevant to climate change provided before and during the review meeting. The time and attention given to preparing for the meeting makes the Subcommittee's review easier and improves our final product. The careful attention by the ACE program to the climate questions described in its StRAP and in the products listed in the tables firmly makes the point that climate change is not only a change happening in the future but is a crucially important set of global, regional, and profoundly local changes happening now. Reducing emissions of the two most important greenhouse gases that drive climate change – carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) – has the added benefit of reducing emissions of particulate matter less than 2.5 microns (PM<sub>2.5</sub>) and hydrocarbons that are ozone precursors. The Subcommittee is very pleased to see the attention that the ACE program has given to characterizing and understanding both current and projected future changes in climate and the effects of these changes on the ACE and EPA mission.

The climate-relevant information and tools for accessing and using that information created with support from the ACE program have broad applications, extending from climate model scenarios selection using EPA's Locating and Selecting Scenarios Online (LASSO) tool through land-use scenarios with EPA's Integrated Climate and Land-Use Scenarios (ICLUS) project, to assessment methods for specific types of adaptation and resilience actions with the Coastal Resilience and Watersheds tools. Work on these tools has successfully processed and packaged science and engineering research from parts of the ACE program for applications by non-technical practitioners for climate adaptation and mitigation, making for technically sound information to inform practical decision-making. The increased emphasis on this type of processing and packaging is a strong sign of the ACE program's enhanced relevance inside EPA and for EPA's overall communication of its mission and products to help sustain the human and natural environment under conditions of changing climate and current significant impacts. This translation aspect of the work created with ACE program support for the term of this review is sufficiently strong that the charge question might better be stated to include not only science to understand climate change impacts, but also to understand and inform long- and short-term responses to impacts across all EPA mission areas.

Not all climate-relevant research area outputs are completely explained or connected to each other in the overall ACE program, however. Product ACE.6.1.3, the dynamically downscaled extreme weather

projections, for example, is important even though very similar products have been developed outside the ACE program. Using the newly developed model outputs to drive new research on the production of precipitation intensity, duration, and frequency (IDF) curves, Product ACE.6.1.4, is a good step toward improved decision-making processes (even though the connection between new IDF curves and the ACE program is not always obvious). Moreover, no set procedure exists for creating IDF curves or for changing those to account for changing climate, so the utility of another set of downscale futures to create another set of IDF curves might not be high.

For this topic, the ACE program could perhaps create a set of products more closely aligned to their StRAP. This could be done by focusing on the particular strengths of the atmospheric modelers in the ACE program who have a deep and rich history of running models in weather mode to support air quality modeling that are similar to the regional climate models used for the IDF curves. In this way, the strengths of ACE program scientists can be focused on improving techniques and answering science questions nearer to the central topics of the program while strengthening links between atmospheric model applications and use for surface water hydrology.

### Strengths

- The ACE program has a large breadth of research projects related to climate that are addressing issues associated with measurements, data evaluation, and interpretation. Modeling is appropriately being used to facilitate synthesis efforts and to address practical applications. The Subcommittee also applauds the development of tools that can be used by a wide range of users, facilitated by collaboration with those who have specific experience in user design.
- The ACE program is responding well to the Administration's focus on climate change and environmental justice. A focus on environmental justice has been well integrated into the ACE program, and, as mentioned earlier in this report, is important for serving the acute needs of disproportionately impacted communities.
- Continued development of extant models and the evolution of new models relevant to specific aspects of climate change is noteworthy. The ACE program has substantially advanced the characterization and understanding of climate change science and climate change effects using new and enhanced combinations of models. EPA clearly recognizes the importance in quantifying the linkages between energy production and its impact on the environment and the climate. More emphasis is needed on the precise identification and estimation of fugitive emissions, including short-lived greenhouse gas (GHG) emissions.
- The Subcommittee applauds the ACE program's development and expansion of CMAQ (Community Multiscale Air Quality Modeling System). CMAQ was originally developed as a model for predicting and simulating air pollutants both spatially and temporally for an urban airshed. The model with various modifications has been extended for use in evaluating linkages between air quality and climate, human health effects of pollutants, contributions of forest fires to air pollutants, watershed acidification, etc. The ACE program appears to have increased the number of scientists working on specific problems and StRAP elements. Bringing in new people with novel ideas for advancing the ACE and EPA missions is a welcome sign.
- The BOSC has previously suggested that more intention be given to the "E" (Energy) aspects of "ACE". The materials provided to the Subcommittee during the October 2021 meeting provide an excellent description of new and continuing work focused on energy. These recent efforts have been effectively integrated into the climate and air pollution research of the ACE program.

## Suggestions

- Less work has been done on climate impacts on the non-human environment. Climate change is having deleterious effects on the biota; for example, food sources, breeding seasons, habitats, and life-cycle patterns are all being disrupted. It is estimated that about 30 percent of all animal and plant species could become extinct by 2070 due to climate change. These impacts have both indirect and direct impacts on humans. The transmission of diseases, diminishment of food and water resources, loss of living space, and extreme weather events will all affect humans and the other plants and animals on the planet. For these reasons, the Subcommittee suggests that the next StRAP include additional research on climate impacts and climate change mitigation or adaptation strategies on non-human populations and ecosystems.
- The Subcommittee would like to see the ACE program produce a synopsis of Agency models currently in use related to climate change, including a table of inputs and outputs, information on temporal and spatial scales, demonstrated applications, and known limitations for use. Furthermore, it would help potential users to know the background and training needed to run each of the models. Where these models are key elements of individual StRAP products, this should be identified. It would also be helpful to indicate which of the models are research-grade and which are production-ready.
- It would be helpful to extend the focus of modeling beyond deterministic representations of results to outputs that represent the probabilistic character of using projected future climate conditions so that results of stand-alone and integrated modeling studies can be presented more fully. This approach is particularly important for results designed for use by non-technical practitioners who would not be familiar with techniques for modeling future climate scenarios. This could be especially helpful for disproportionately impacted communities experiencing some of the most serious effects of climate change.
- We suggest the ACE program consider explicitly identifying products that are repackaged for informing specific types of mitigation or adaptation decisions. These products are important elements of helping the public and others understand the impact and use of the science, translating it for their decision-making needs.

## Recommendations

The Subcommittee offers the following recommendations:

**Recommendation 2.1:** Provide information to users within the ACE program and ORD and to the public that helps explain potential applications of existing and developing models for describing and evaluating current conditions and future projections related to climate change threats and impacts. It would be most helpful for this information to include summaries of completed projects, which include model evaluation steps and records of how models were chosen for specific questions.

**Recommendation 2.2:** Ensure that climate-relevant emissions from agricultural operations, chiefly of CH<sub>4</sub>, reduced and oxygenated nitrogen, and VOCs, are included in the modeling and observational work across the ACE program. We encourage the program to build on the success of previous collaborations and expand connections to USDA and the Agricultural Research Service (ARS), for example, to help address key data and information gaps.



## Charge Question 3

Q.3: The Nation's energy and transportation systems are experiencing major transformations in response to economic drivers and to meet the Biden Administration's goal of net-zero carbon emissions by 2050. Understanding the dynamic changes in these complex, interconnected systems is important for understanding impacts of policies and technology changes on emissions of greenhouse gases, air pollutants, and other health and environmental impacts.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD's implementation of its research portfolio to gain a better understanding of how energy and transportation systems may evolve and the consequences for emissions and other impacts. [RA5]*

### Narrative

ACE Research Area 5 is focused on methods (i.e., models, tools, and databases) to evaluate the environmental benefits and consequences of changing energy systems in the United States. The priorities and direction for this research area generally come from program and regional offices as the former consider new regulatory scenarios or international obligations and the latter support planning of the energy transition in cities and regions that often have unique constraints. While much of the modeling effort is focused on air quality, multimedia impacts have become important: for example, regional water use in future energy scenarios or soil and water impacts from renewable fuel production. Significant model development efforts have been invested in making the Global Change Analysis Model (GCAM-USA) more accessible to a wide range of analysts and decision-makers through the use of the GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator (GLIMPSE) tool. ORD developed the EPAUS9rT database for use with the TIMES model, which has been used to examine future scenarios for green hydrogen use in the transportation section and sector decarbonization strategies. The ACE program developed COMET, an evaluation tool for cities and states that can support long-term energy sector planning, taking into account sustainability, resilience, and equity. As mandated by Congress, the ACE program is leading work on The Third Triennial Biofuels report to Congress. This work involves modeling and analysis of the effects of the Renewable Fuel Standard (RFS) Program on air, water, and soil, terrestrial and aquatic ecosystems, and international impacts. The ACE program collaborates within EPA (program and regional offices), with other agencies, and with outside groups on these efforts. Significant research is published in the peer-reviewed literature.

The current Administration's emphasis is on combating climate change and ensuring environmental justice. The Subcommittee notes that it will be critical to ensure that environmental justice is fully considered in the context of the energy transformation to renewable sources. The potential exists for disproportionate impacts through legacy site retirement/redevelopment, siting of new generation assets (e.g., renewables), and the emerging green hydrogen economy. Support for these areas can be enhanced when prioritizing resource allocation for future modeling and database research as discussed below. The modeling tools and databases developed by the ACE program are increasingly valued and used by researchers and policymakers within and external to EPA. Dissemination of these products for effective use requires technical support and science translation skills, which will require rethinking staffing needs and reward structures within ORD.

### Strengths

- The ACE program has developed a strong suite of energy and transportation models forecasting multi-pollutant air emissions at different geographic (global, national, community-level) and time (near-

term, 2050) scales for a wide range of sectors and policies (e.g., electric vehicle, or EV, and hydrogen use in transportation, deep energy system decarbonization). ACE energy modeling is clearly valued by EPA program and regional offices.

- EPA is working with other agencies (e.g., USDA, the U.S. Department of Energy [DOE], the National Oceanic and Atmospheric Administration [NOAA]) to assess the impacts to date (i.e., air, water, and soil quality; water availability, terrestrial and aquatic ecosystems; wetlands; invasive species, international effects) as well as likely future effects of the RFS Program. The Third Triennial Biofuels report is in progress and ORD is conducting key modeling analyses. For example, the ACE program used the EPIC (Environmental Policy Integrated Climate) model to conclude that grassland-to-cropland conversion increased soil, nutrient, and carbon losses in the Midwest between 2008 and 2016 (Zhang et al., 2021).<sup>5</sup>
- The ACE program has a good track record of peer-reviewed publications reporting energy modeling frameworks and results. The Subcommittee applauds the effective dissemination of energy system models to a variety of users, facilitated by the ACE program. For example, dissemination to EPA regions (e.g., Connecticut analysis of state clean energy and climate policies and their multi-pollutant, environmental impacts to help attain the ozone NAAQS) and other users. The ACE program is also proactive in interacting with users and stakeholders. An excellent example is the interactions with international universities and developing countries that use the EPAUS9r-TIMES energy system optimization model.
- The ACE program has productive and important partnerships with other offices and agencies, as well as with external groups such as the Energy Modeling Forum, for testing and improving models. For example, ACE program researchers have participated in a variety of cross-agency workgroups. These include a DOE-led workgroup on carbon capture and sequestration, an ongoing workgroup on “Scenarios and Interoperability,” workgroups on annual updates to Annual Energy Outlook such as “Oil and Gas Workgroup” and the “DOE-DOT-EPA Information Exchange on Connected, Autonomous, Shared, Electric Vehicles.” ACE program researchers also collaborate through Interagency Agreements (IAs). These include a previous IA with the National Renewable Energy Laboratory (NREL) in which they obtained characterizations of wind resources and recent and ongoing IAs with the Pacific Northwest National Laboratory (PNNL) for GCAM-related research. These engagements help ensure that the ACE program scientists are engaged with and influential in the broader research community.

### Suggestions

- The Subcommittee suggests that the ACE program consider adding a capability to quantify the health impacts of building decarbonization activities in response to clean energy policies. The ACE program is already investigating the benefits of reduced residential wood combustion, but this could be expanded to include ventilation and filtration changes to reduce energy use while preserving and improving indoor air quality, and reduction of indoor combustion resulting from all-electric houses.
- The Subcommittee suggests that the ACE program consider adding a capability to COMET to quantify the health benefits from increases to active modes of transportation in response to clean transportation and sustainable community policies, including more walking and cycling.
- The Subcommittee suggests that the ACE program consider an explicit focus on the short-lived climate pollutants (i.e., CH<sub>4</sub>, hydrofluorocarbons [HFCs], black carbon, VOCs/carbon monoxide [CO]). The recently released Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concludes these pollutants have a roughly equivalent collective climate impact to CO<sub>2</sub> even though

<sup>5</sup> Zhang, et al. (2021) Grassland-to-cropland conversion increased soil, nutrient, and carbon losses in the US Midwest between 2008 and 2016, *Environ. Res. Lett.*, 16 (5): 054018, <https://iopscience.iop.org/article/10.1088/1748-9326/abebe>.

they are resident in the atmosphere for much less time than CO<sub>2</sub>. Therefore, it is necessary to reduce emissions of the short-lived climate pollutants to lower the probability of triggering catastrophic climate tipping points. In many cases, these short-lived climate pollutants intersect with energy systems, such as fugitive CH<sub>4</sub> releases from oil and gas production and landfill gas capture systems, low-GWP (global warming potential) refrigerants (e.g., ammonia, propane) that can be deployed safely and can be less expensive and more energy efficient than HFCs, and black carbon and VOC/CO reductions from clean energy and transportation policies. In some cases, these sectors intersect with environmental justice issues, such as co-emitted toxics from combustion processes that are disproportionately located in some communities already impacted by other pollution sources.

- The Subcommittee suggests that the research on scenario development be evaluated and potentially expanded to ensure that emerging energy technologies and systems are sufficiently addressed. For example, hydrogen and other energy carriers (e.g., ammonia, synthetic hydrocarbons) are expected to play a more prominent role in the energy system in the coming years but are not currently reflected in the ACE program's modeling activities or projections. Ad-hoc coordination across groups on these issues may be inadequate.
- The Subcommittee notes that the reward structure for ORD/ACE program scientists currently favors traditional scientific metrics (e.g., publication record). This focus can potentially impede the dissemination of research results to some stakeholders, as well as support to users of different models and tools, since these activities are not key performance metrics. The Subcommittee suggests that ORD and the ACE program consider alternative reward structures to ensure that a broader definition of scientific leadership is recognized and prioritized.

## Recommendations

The Subcommittee offers the following recommendations:

**Recommendation 3.1:** Include the impacts of policies and technology changes on communities with environmental justice issues in the ACE program's work on the changing energy and transportation systems. These communities have historically suffered disproportionately poor health outcomes related to air pollution generated from industrial processes and the transportation system.

**Recommendation 3.2:** Prioritize two specific areas in terms of continued support and additional assistance: (1) more intentional coordination with the user community on outreach, training, and support for tools and databases; and (2) approaches to optimize dissemination of information and model results to a broad set of stakeholders.

## SUMMARY LIST OF RECOMMENDATIONS

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**Charge Question 1:** The ACE research program is implementing research to develop new methods to quantify source and near-source emissions, as well as ambient levels, of toxic air pollutants and contaminants of emerging concern. These methods are needed to identify pollutant sources and levels of exposure for communities and individuals.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD's implementation of its air toxics and contaminants of emerging concern measurements methods research, and how this research*

*will improve our understanding of these pollution sources and exposures, particularly for disproportionately impacted communities? [RA1, RA2, RA4]*

- **Recommendation 1.1:** Coordinate with states to provide recommendations for consistent and standardized procedures to collect and analyze EtO samples. Recommendations are needed in particular to ensure more sensitive methods are applied consistently and can be compared across agencies.
- **Recommendation 1.2:** Develop a strategy for toxicity-linked data (health outcomes) as part of the broad research on understanding the impact of VCPs and secondary organic aerosols (SOAs) on health and the environment. This can help illuminate the specific pollutants causing substantial health effects and the chemical and/or physical properties causing the most toxic effects on communities.
- **Recommendation 1.3:** Develop materials (documents/tools) to help the public better understand the outcomes and implications of the significant amount of health-effects research ongoing in the ACE program. Prioritization of public messaging will enable citizens to make more informed choices to avoid exposure.

**Charge Question 2:** Climate change is expected to continue to increase the negative environmental and human health impacts of wildfires, flooding, drought, and other extreme events. Developing the knowledge and approaches to build resilience and adapt to these events is critical to preparing communities and protecting vulnerable populations and ecosystems.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD's implementation of research to understand effects of climate-driven changes on natural and human systems, adverse impacts on human health and the environment from climate stressors, and approaches to prevent or reduce these impacts? [RA6]*

- **Recommendation 2.1:** Provide information to users within the ACE program and ORD and to the public that helps explain potential applications of existing and developing models for describing and evaluating current conditions and future projections related to climate change threats and impacts. It would be most helpful for this information to include summaries of completed projects, which include model evaluation steps and records of how models were chosen for specific questions.
- **Recommendation 2.2:** Ensure that climate-relevant emissions from agricultural operations, chiefly of CH<sub>4</sub>, reduced and oxygenated nitrogen, and VOCs, are included in the modeling and observational work across the ACE program. We encourage the program to build on the success of previous collaborations and expand connections to USDA and the Agricultural Research Service (ARS), for example, to help address key data and information gaps.

**Charge Question 3:** The Nation's energy and transportation systems are experiencing major transformations in response to economic drivers and to meet the Biden Administration's goal of net-zero carbon emissions by 2050. Understanding the dynamic changes in these complex, interconnected systems is important for understanding impacts of policies and technology changes on emissions of greenhouse gases, air pollutants, and other health and environmental impacts.

*What suggestion(s)/recommendation(s) does the Subcommittee have on ORD's implementation of its research portfolio to gain a better understanding of how energy and transportation systems may evolve and the consequences for emissions and other impacts. [RA5]*

- **Recommendation 3.1:** Include the impacts of policies and technology changes on communities with environmental justice issues in the ACE program's work on the changing energy and transportation systems. These communities have historically suffered disproportionately poor health outcomes related to air pollution generated from industrial processes and the transportation system.
- **Recommendation 3.2:** Prioritize two specific areas in terms of continued support and additional assistance: (1) more intentional coordination with the user community on outreach, training, and support for tools and databases; and (2) approaches to optimize dissemination of information and model results to a broad set of stakeholders.

## APPENDIX A: MEETING AGENDA

### Tuesday, October 12, 2021

Time (EDT)	Agenda Activity	Presenter
10:30 – 11:00	Sign on & Technology Check	
11:00 – 11:15	Welcome and Opening Remarks	Tom Tracy, Designated Federal Officer (DFO)  Charlette Geffen, ACE BOSC SC Chair Sandy Smith, ACE BOSC SC Vice Chair
11:15 -11:30	ORD Welcome	Wayne Cascio, ORD Acting Principal Deputy Assistant Administrator for Science
11:30 – 11:45	Overview of ACE BOSC SC Meeting Format and Charge Questions	Bryan Hubbell ACE National Program Director (NPD)
11:45 – 11:55	Update on BOSC EC PFAS Research Discussion	Susan Burden, OSAPE
<b>Charge Question 1</b>		
11:55 – 12:10	<b>CQ1:</b> Science Needs Related to Air Toxic Sources and Emerging Contaminants (Research Areas 2 and 4)	Bryan Hubbell, ACE NPD
12:10 – 12:25	Approaches for Addressing Scientific Challenges and Key Uncertainties in Characterizing Air Toxics and Contaminants of Emerging Concern	Alice Gilliland, Acting Center Director, Center for Environmental Measurement and Modeling (CEMM)
12:25 – 1:55	Research to Understand Source Emissions and Ambient Concentrations of Air Toxics and Contaminants of Emerging Concern	Tiffany Yelverton, CEMM Richard Shores, CEMM Alan Vette, CEMM Chet Wayland, OAR
1:55 – 2:10	<b>BREAK</b>	
2:10 – 4:10	<b>Meet the Scientists, Session #1</b>	
	<b>Room A</b>	
	Air Toxics – Source Measurement and Methods, Session Lead	Wyat Appel, CEMM
	PFAS Methods Development	Jeff Ryan, CEMM
	Fenceline Measurements and Methods Development	Eben Thoma, CEMM
	PFAS Incineration	Jonathan Krug, CEMM
	<b>Room B</b>	
	Air Toxics – Ambient Measurement and Methods, Session Lead	Mike Hays, CEMM
	VOCs/Odor Explore App	Rachelle Duvall, CEMM
	EtO Ambient Measurement and Methods Development	Ingrid George, CEMM
	Air Toxics Ambient Measurement and Methods Development	Tamira Cousett, CEMM
	<b>Room C</b>	
	Air Toxics Modeling and Databases, Session Lead	Donna Schwede, CEMM

Time (EDT)	Agenda Activity	Presenter
	Incorporating PFAS into the CMAQ Model	Emma D'Ambro, CEMM
	Updates to the SPECIATE database	George Pouliot, CEMM
	Adding VCP Chemistry to CMAQ	Havala Pye, CEMM
4:10 – 4:25	<b>BREAK</b>	
4:25 – 4:40	Public Comments	Tom Tracy, DFO
4:40 – 5:15	Clarification Questions from BOSC SC	Charlette Geffen, ACE BOSC SC Chair Sandy Smith, ACE BOSC SC Vice Chair
5:15 – 6:15	Working Session for BOSC SC Discussion	

**Wednesday, October 13, 2021**

Time (EDT)	Agenda Activity	Presenter
10:30 – 11:00	Sign on & Technology Check	
11:00 – 11:15	Welcome Back	Tom Tracy, DFO Charlette Geffen, ACE BOSC SC Chair Sandy Smith, ACE BOSC SC Vice Chair
<b>Charge Question 2</b>		
11:15 -11:30	<b>CQ2:</b> Science Needs to Understand Climate Change Impacts (Research Area 6)	Andy Miller, ACE Associate NPD for Climate
11:30 – 11:45	Approaches to Understand and Prepare for Climate-Driven Impacts	Tim Watkins or TBD, Acting Center Director, Center for Public Health and Environmental Assessment (CPHEA)
11:45 – 1:15	Research to Understand Climate Impacts and to Enable Resilience	Peter Beedlow, CPHEA Britta Bierwagen, CPHEA Chris Weaver, CPHEA Stephanie Santell, OW Dan Brown, R10 Jeremy Martinich, OAP
1:15 – 1:30	<b>BREAK</b>	
1:30 – 3:30	<b>Meet the Scientists, Session #2</b>	
	<b>Room A</b>	
	Water Quality and Aquatic Resources, Session Lead	Darrell Winner, CPHEA
	Stormwater Best Management Practices	Tom Johnson, CPHEA
	Adaptation Planning Frameworks	Jordan West, CPHEA
	Regional Watershed Resilience	Naomi Detenbeck, CEMM
	<b>Room B</b>	
	Ecosystem Effects, Session Lead	Peter Beedlow, CPHEA
	Coldwater Fish Refugia	Joe Ebersole, CPHEA
	Nutrient Transport	Jana Compton, CPHEA
	<b>Room C</b>	
	Scenarios and Impacts, Session Lead	Tanya Spero, CEMM
	Global Change Explorer	Phil Morefield, CPHEA

Time (EDT)	Agenda Activity	Presenter
	Storm IDF curves	Anna Jalowska, CPHEA
3:30 – 3:45	<b>BREAK</b>	
3:45 – 4:15	Public Comments	Tom Tracy, DFO, OSAPE
4:15 – 4:45	Clarification Questions from BOSC SC	Charlette Geffen, ACE BOSC SC Chair Sandy Smith, ACE BOSC SC Vice Chair
4:45 – 5:30	Working Session for BOSC SC Discussion	

**Thursday, October 14, 2021**

Time (EDT)	Agenda Activity	Presenter
10:30 – 11:00	Sign on & Technology Check	
11:00 – 11:15	Welcome Back	Tom Tracy, DFO, OSAPE Charlette Geffen, ACE BOSC SC Chair Sandy Smith, ACE BOSC SC Vice Chair
<b>Charge Question 3</b>		
11:15 – 11:25	<b>CQ3:</b> Science Needs for Impacts of Changing Energy Systems (Research Area 5)	Sherri Hunt, ACE Principal Associate NPD
11:25 – 12:15	Approaches and Research to Understand Impacts of Changing Energy Systems	Darrell Winner, CPHEA Rebecca Dodder, CEMM Marcus Sarofim, OAP Shutsu Wong (R1)
12:15 – 12:30	<b>BREAK</b>	
12:30 – 2:00	<b>Meet the Scientists Session #3</b>	
	<b>Room A</b>	
	Energy Systems Modeling and Databases, Session Lead	Tom Pierce, CEMM
	GLIMPSE	Dan Loughlin, CEMM
	EPAUS9r-TIMES	Carol Lenox, CEMM
	CoMET	Ozge Kaplan, CEMM
	<b>Room B</b>	
	Biofuels, Session Lead	Britta Bierwagen, CPHEA
	Biofuels Report to Congress	Chris Clark, CPHEA
	Terrestrial Effects of Land Use Change	Steve LeDuc, CPHEA
2:00 – 2:15	<b>BREAK</b>	
2:15 – 3:15	Revitalizing Research to Address the Challenge of Climate Change	Bryan Hubbell, ACE NPD Andy Miller, ACE ANPD for Climate
3:15 – 4:00	Clarification Questions from BOSC SC	Charlette Geffen, ACE BOSC SC Chair Sandy Smith, ACE BOSC SC Vice Chair
4:00 – 5:00	BOSC SC Workgroup Breakouts	
5:00 – 5:45	BOSC SC Workgroup Reports	
5:45 – 6:00	Wrap up and Next Steps	Charlette Geffen, ACE BOSC SC Chair Sandy Smith, ACE BOSC SC Vice Chair
6:00	Adjourn	Tom Tracy, DFO



## APPENDIX B: MATERIALS

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### Material Provided in Advance of the Meeting

- Agenda
- Charge questions
- Summary of Product and Output Information for the Air and Energy 2019-2022 StRAP
- CQ1: Science Needs Related to Air Toxic Sources and Emerging Contaminants
- CQ2: Science Needs to Understand Climate Change Impacts
- CQ3: Science Needs for Impacts of Changing Energy Systems
- Projects Relevant to the Charge Questions and Supported through the Science to Achieve Results (STAR) Extramural Grants and Other Supplemental Internal ORD programs
- Tools and Resources Developed by ORD to Understand Impacts of the Changing Climate and Inform Adaptation

### Material Provided During or After the Meeting

- PowerPoint presentation slides presented during the meeting
- ORD responses to BOSC follow-up questions